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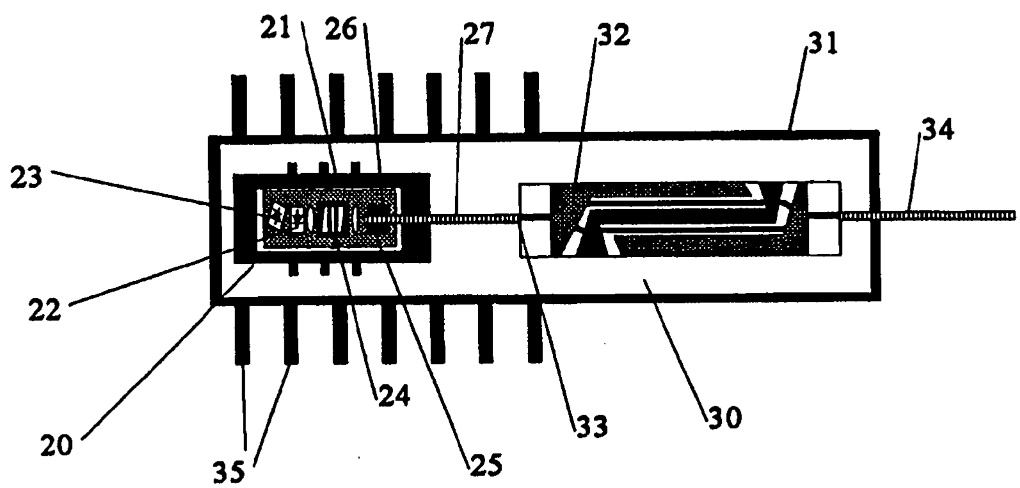

(57) Abstract

An optical transmitter module comprises a single package (21) enclosing a laser assembly (22, 23, 24) and an integrated optical circuit (32) having an input waveguide and an output waveguide. An optical fibre stub (27) optically interconnects the laser assembly and the optical circuit (32), the fibre stub (27) having one end supported to receive light from the laser assembly and the other end (33) optically coupled to the input waveguide of the optical circuit. An output optical fibre (34) is in optical communication with the output waveguide of the optical circuit and leads out of the package, whereby light emanating from the laser assembly is fed to the optical circuit and is there subjected to data-encoding before leaving the package through the output optical fibre.

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LASER MODULATORS

This invention relates to an optical transmitter module, suitable for use in telecommunications networks employing optical fibres.

In long-haul (i.e. typically > 200 km) telecommunications networks, the conventional practice for modulating light generated by a laser for transmission along a fibre has been to employ a high powered laser and a separate external modulator, each having its own short connecting fibres (usually referred to as 'pigtails') connected together, and the modulator having an output pigtail for connection to a network fibre or some other component. This has been because it is easier to manufacture a laser as a separate unit, if it is to have a narrow line width. Also, it is easier to manufacture a suitable modulator having a chirpless characteristic at data rates of up to 2.5 Gb/s, if it is a separate component. An external modulator of this kind is generally fabricated on a lithium niobate wafer, which is not a suitable material for the generation of the optical emission itself. Thus, the usual system has been to employ a discretely packaged laser diode and a discretely packaged optical modulator, coupled together by their respective pigtails. By employing this combination of a cw laser and an external modulator, operators can install links of up to 600 km using existing terrestrial fibre, without the need for electrical regeneration.

Due to polarisation dependency issues with the modulator, the pigtails interconnecting the laser module and the modulator must be of polarisation-maintaining optical fibre, for the overall assembly to operate effectively. This increases the cost of the laser module since it requires special setting up procedures at the time of connecting thereto a polarisation-maintaining fibre. Moreover, the pigtail from the laser must be connected to the pigtail to the modulator either with a polarisation-maintaining fusion splice or with pre-aligned optical connectors. Either of these solutions is difficult to implement and leads to significant further costs.

The modulator may be manufactured using materials other than lithium niobate, such as gallium arsenide and indium phosphide, but the preferred modulator designs are still polarisation sensitive and must still therefore be used with polarisation-maintaining optical fibre, between the laser module and the

modulator.

In an attempt to overcome the above difficulties, and also to increase the packing density of components on circuit boards, there has been a drive to eliminate the pigtail interface between a laser module and a modulator. This has lead to the evolution of so-called integrated laser-modulator devices, falling into either monolithic or hybrid categories.

In a monolithic laser-modulator device, the modulator is fabricated into the same wafer as the laser, by multiple deposition and etching stages. Generally, electro-absorption modulators have been used, where the modulator section is fabricated with a band-gap such that the absorption edge of the material matches the laser emissions. In this way, a small applied electric field will shift the band-gap so that the material absorbs. Unfortunately, this has the effect of causing chirp within the structure, from a variety of sources. Also, the fabrication of these devices has a relatively low yield due to the requirement to match a band-gap over two manufacturing growth stages. This device is thus not favoured for wavelength-division multiplexed networks.

A hybrid solution allows the optimal performance of a narrow line width laser to be coupled to an external modulator, but still within the same package. Both direct laser-modulator coupling and the use of intermediate optics have been employed, as illustrated in Figures 1 and 2 of the accompanying drawings.

Referring to Figure 1, a laser 10 is butt-coupled to a modulator 11, so that the modulator directly receives emission from the laser. The output from the modulator is taken by an optical fibre pigtail 12 out of a package 13 within which both the laser 10 and the modulator 11 are hermetically sealed. In this way, polarisation-maintaining optical fibre, lenses and an optical isolator, associated with separate laser module and modulator, are all eliminated. Despite this, the laser may suffer adverse effects due to the high reflectivity interface unless the modulator end-facet is angled or bevelled to direct reflections away from the active stripe of the laser.

The laser and sometimes both the laser and the modulator are mounted on a Peltier cooler 14 (that is, a thermo-electric cooling element) so that the temperature of the laser can be maintained accurately at the required value to

ensure emission at a precise wavelength, the wavelength being monitored externally of the device. In addition, a monitor photodiode 15 is incorporated within the laser so that the output power of the laser may be monitored and the drive current thereto controlled to stabilise the laser power.

With wavelength division multiplexing systems, the emission wavelength is usually fine-tuned by controlling the temperature of the Peltier element 14, and a reduction in the quality of the control of the temperature will have an adverse affect on the network performance.

Figure 2 shows the alternative approach of employing an intermediate optical train between the laser and the modulator, including lenses 16 and an optical isolator 17, to prevent reflected light passing back to the laser diode. The optical train is similar to that employed with a discrete laser package but the final lens is chosen to accommodate the mode size of the waveguide geometry, to allow light from the laser to enter the modulator waveguide.

A particular disadvantage of the arrangement of Figure 2 is that the isolator is normally a single stage design, due to cost considerations, and hence rotates the polarisation by only 45°. The emission plane of the laser and that required by the modulator are the same when the elements are placed on a common flat plane. The solution to this is to employ compound isolators in order to achieve either an initial +45° and a further +135° (i.e. 180° in total), or +45° and then -45° polarisation rotation so that the required relative laser and modulator polarisation orientation is obtained. However, this has the effect of greatly increasing the manufacturing costs of the devices due to the isolator costs.

A draw-back associated with the two designs described above and illustrated in Figures 1 and 2 is that the Peltier element is associated only with the laser. This is done to ensure sufficient responsiveness of the closed-loop feedback circuit for driving the Peltier element and it also significantly reduces the power consumption of the Peltier element. Driving of the Peltier element causes the thickness of that element, and so the height of the laser, to be changed by at least a few microns but perhaps up to a few tens of microns and this affects the coupling of the laser to the modulator. In turn this gives rise to

variations in output power, with temperature. The alternative to this is to place all the components on the Peltier element, but this could result in considerably increased power consumption of the Peltier element, and a slowing in the responsiveness of temperature control loops maintaining the Peltier element temperature, due to the increased thermal loads and masses.

The present invention aims at overcoming the disadvantages of the direct and indirect hybrid laser-modulator packages described above, particularly with reference to Figures 1 and 2.

In accordance with the present invention, there is provided an optical transmitter module an optical transmitter module comprising packaging means enclosing a laser assembly, an integrated optical circuit having an input waveguide and an output waveguide, an optical fibre stub having one end supported to receive light from the laser assembly and the other end of the optical fibre stub being optically coupled to the input waveguide of the optical circuit, and an output optical fibre in optical communication with the output waveguide of the optical circuit and leading out of the packaging means, whereby light emanating from the laser assembly is subjected to data-encoding by the optical circuit before leaving the packaging means.

In a preferred form of this invention, illustrated in Figure 3 and 4 of the accompanying drawings the laser assembly is in the form of an hermetically-sealed sub-module mounted within said packaging means, the optical fibre stub entering in a sealing manner the laser sub-module to receive light from the laser assembly. A non-hermetically-sealed sub-module could instead be employed. In either case, the fibre stub is connected internally of the sub-module to the laser, so that optical alignment with the stub is maintained at all times. However, by closely coupling the optical modulator directly to the fibre stub and packaging together both the laser module and the modulator, the disadvantages of having external pigtails are wholly avoided. The optical fibre stub may be only a few mm long, at the most, and its free end is preferably directly connected to the modulator end face, in communication with the waveguide. Such a fibre need not be polarisation maintaining, in view of its very short length, and thus such a structure is relatively simple and cheap to implement.

In an alternative embodiment of this invention, shown in figs 5A, 5B and 5C of the accompanying drawings, a mounting element is provided within the packaging means and carries the laser assembly, and support means is provided on the mounting element for supporting the said one end of the optical fibre adjacent the laser assembly. Thus, in this embodiment a laser assembly is packaged together with an integrated optical circuit, with light being supplied to the optical circuit from the laser assembly through the optical fibre stub. In order to ensure that the end of the stub adjacent the laser assembly always is in optical alignment with that laser, a mounting element configured expressly to support the end of the fibre stub is carried on the same mounting element as the laser itself together with any other required optical components to couple the output of the laser into the stub. In this way, optimum coupling may be maintained at all times notwithstanding any dimensional variations in the mounting element.

The invention is particularly applicable to a case where the mounting element comprises a Peltier cooler, with which significant dimensional changes may be expected dependent upon the drive current thereto. Even despite significant variations in the driving current to the cooler, accurate alignment may still be expected, optimising the coupling of light from the laser, to the optical circuit.

In another embodiment of this invention, shown in figs 6A, 6B, 7A and 7B of the accompanying drawings, the packaging means has a base wall and one of the laser assembly and the integrated optical circuit is carried on a mounting surface which lies at an acute angle to the base wall whereby the polarisation plane of light leaving the laser assembly matches the launch polarisation plane of the integrated optical circuits.

Typically, an optical isolator included in the laser assembly rotates the plane of polarisation of light emitted by the laser through $+\alpha°$; in this case, said mounting surface should lie at $-\alpha°$, for a modulator requiring TE polarisation (that is, parallel to the package base wall). In a case where the modulator requires TM polarisation, said mounting surface should lie at $(90 - \alpha)°$ to the base wall. In either case, by employing a mounting surface in accordance with

this embodiment of the invention, the plane of polarisation of the light leaving the laser assembly will be properly matched to the launch polarisation plane for the modulator. Normally, the isolator will rotate the plane of polarisation by 45° and then the mounting surface should lie at 45° to the plane of the base wall.

The mounting surface preferably is defined by a sub-mount provided with the package and secured either directly to the package base wall or indirectly to that base wall by means of a Peltier cooler element.

In one embodiment of this invention, the laser assembly includes the laser-diode which is carried on the mounting surface. In this case, the optical isolator preferably also is carried on the mounting surface. In the alternative, the integrated optical circuit is carried on the mounting surface, the laser assembly then being carried in a conventional manner, on a sub-mount itself supported by a Peltier cooler.

The laser assembly may be directly coupled to the optical circuit, a lens being provided to direct the output of the laser assembly into the input waveguide of the modulator. In the alternative, an optical fibre stub may be provided optically to interconnect the laser assembly and the input waveguide of the integrated optical circuit.

The laser assembly may include a tunable source such that a laser element in the assembly emits light at a single discrete wavelength dependent upon the tuning of the source. This may be achieved by monitoring the output from the laser, which typically will be a laser diode, and then providing a suitable feedback signal to the laser in order to control the wavelength of the emission. The feedback may be achieved optically, or electronically.

The packaging means may comprise a package similar to that conventionally employed for a modulator, except that it may need to be slightly larger in order to accommodate the laser assembly. Thus, the packaging means may comprise a base wall on which the laser assembly and the integrated optical circuit are separately mounted, side walls upstanding from the base wall, and a cover sheet sealed to the side walls so as wholly to enclose the laser assembly and the integrated optical circuit. Such packaging means

advantageously is hermetically-sealed to isolate the optical circuit from the external environment.

The laser assembly may be of an essentially conventional design and thus including a Peltier cooler, to control the wavelength of the laser, the wavelength being tracked externally of the device or by using a filter arrangement as described above .

The integrated optical circuit may be a modulator of a known suitable design for the intended use of the transmitter module. Thus, it may comprise a phase modulator or a Mach-Zehnder interferometer, typically fabricated on a lithium niobate wafer, though other modulator designs may be used.

By way of example only, various embodiments of the invention will now be described in further detail, reference being made to the accompanying drawings, in which:-

Figures 3 and 4 respectively show isolated and non-isolated laser sub-modules packaged together with an optical modulator to form two embodiments of optical transmitter modules of this invention;

Figure 5A diagrammatically shows a plan view of an isolated laser assembly packaged together with an optical modulator, to form a second embodiment of this invention;

Figure 5B is an enlarged view on a part of the laser assembly of Figure 5A; and

Figure 5C is a sectional view on line A-A marked on Figure 5B;

Figure 6A is a diagrammatic plan view on a third embodiment of this invention;

Figure 6B is a section taken on line A-A marked on Figure 6A; and

Figures 7A and 7B are similar to Figures 6A and 6B, but of a fourth embodiment.

First and Second Embodiments (Figures 3 and 4)

In Figure 3, there is shown a compact laser sub-module 20 comprising an hermetically sealed package 21 within which is enclosed a laser diode 22, a monitor photodiode 23 and an optical train 24 including lenses and an optical isolator, shielding the laser diode from reflected light. These components are

mounted on a Peltier cooler 25 which also supports a fibre mount 26 carrying an end portion of a fibre stub 27 leading out of the package 21 in an hermetically-sealed manner. The end of the fibre stub 27 is appropriately prepared to receive light from the optical train 24 and is mounted in accurate alignment with the optical train in order to receive the maximum emission from the laser. The lens nearer the fibre may be micro-manipulated in order to optimise the coupling of the laser emission to the fibre stub, before all the components are secured in position.

The laser sub-module 20 is mounted to the base wall 30 of an overall package 31 of a known general design, which package also includes four side walls upstanding from the base wall and a cover sheet (not shown). The base wall 30 supports an optical modulator 32, fibre stub 27 being directly connected at 33 to the input waveguide of the optical modulator. A fibre pigtail 34 is connected to the output waveguide of the modulator and leads out of the package 31, for connection to another fibre or another network component. Suitable electrical connections are made from pins 35 of the package 31 to connecting pins of the laser sub-module 20 and also to the electrodes of the modulator 32.

Suitable means may be provided to permit tuning of the emission wavelength of the laser diode 22. For example, an optical feedback arrangement may be provided to control the frequency at which the diode 22 lases, or an electronic control may instead be utilised.

Figure 4 illustrates a similar arrangement to that of Figure 3 except that the laser sub-module does not include an optical isolator. Like components with those of Figure 3 are given like reference characters and will not be described again here.

The use of an un-isolated laser sub-module 20 allows the cost to be reduced very significantly, as an optical isolator represents a very high proportion of the raw material cost of a laser module. It is possible to eliminate an optical isolator by employing radiused or angled fibre end-faces within the laser module, and also angled fibre/optical circuit interfaces, so as significantly to reduce near-end reflections. Such an approach is better suited to short-haul

local area networks or network access applications where link lengths and performance are not quite so critical as with long-haul systems. By contrast, for long haul systems an isolated laser module as shown in Figure 3 may be the preferred solution.

The above described embodiments of this invention have the following advantages:

a) The laser sub-module may be manufactured and tested before incorporation within the overall package and this leads to high manufacturing yields, since bare-chip lasers are eliminated;

b) The manufacturing process for connecting a fibre to the modulator may employ materials (such as an epoxy resin) which are incompatible with a laser diode, as the laser is hermetically sealed;

c) The laser-modulator interface is optically compliant and maintains optimum optical coupling, eliminating the temperature effects of the Peltier element;

d) The physical size of the Peltier element may be reduced to a minimum, so reducing the element power consumption and increasing the effectiveness of the closed-loop control;

e) A short fibre stub of singlemode fibre will effectively maintain polarisation between the laser and the modulator, so eliminating the need for polarisation-maintaining fibre in non-critical applications; and

f) In the event that polarisation maintaining optical fibre is employed, the fibre stub may be rotated to achieve the required launch polarisation, so eliminating the need for an isolator of increased complexity.

Third Embodiment (Figures 5A, 5B & 5C)

In Figure 5A, there is shown a laser assembly 120 comprising a laser-diode 121, a monitor photo-diode 122 and an optical train 123 including lenses and an optical isolator, shielding the laser diode 121 from reflected light. These components are supported on a sub-mount 124 which is itself mounted on a Peltier cooler 125, secured to a base wall 126 of the overall package 127. The laser diode 121 could be mounted on an individual sub-mount, with the other components then being mounted directly on the Peltier cooler 125.

Also mounted on the base wall 126 is an optical modulator 128 arranged as a Mach-Zehnder interferometer of a known design, fabricated in a lithium niobate wafer in a manner known in the art. The input waveguide 129 of the modulator 128 is coupled to the laser assembly by means of an optical fibre stub 130, one end of which is disposed within the laser assembly and the other end of which is directly attached to an end face of the modulator, in direct communication with the input waveguide 129.

A support block 132 (see also Figures 5B and 5C) is attached, for example by laser-welding, to the Peltier cooler 125, for supporting the end of the fibre stub 130 within the laser assembly, on the optical axis thereof. A pair of saddles 133 are provided to secure the fibre to the support block 132. In order to optimise the collection of light from the laser diode 121, the end face of the fibre within the laser assembly may be treated so as to form a lens.

During manufacture of the transmitter module shown in Figure 3, the fibre stub 130 is manipulated with reference to the laser on its sub-mount 124. When the optimum alignment has been achieved, the saddles 133 are laser-welded to the fibres and then the saddles are laser-welded to the support block 132. Final optimisation of the coupling may be achieved by micro-manipulation of the lens nearer the fibre stub and then securing, by laser-welding, a carrier for the lens to the sub-mount 124.

In addition to the base wall 126, the package 127 includes four side walls upstanding from the base wall and also a cover sheet (not shown). Suitable electrical connections are made from the pins 134 of the package 127, to the laser diode 121, monitor photo-diode 122 and the optical modulator 128 as well as to the Peltier cooler 125, to permit proper driving of these various components.

With the arrangement as described above, notwithstanding any variations in thickness of the Peltier cooler 125 consequent upon the drive current supplied thereto, the optical power fed into the optical modulator by the fibre is constant since the optical alignment is at all times maintained and the laser assembly/modulator interface (provided by the fibre stub) is not subjected to any stress from dimensional changes of the Peltier element.

Fourth and Fifth Embodiments (Figures 6A and 6B: Figures 7A and 7B)

Referring initially to Figures 6A and 6B, there is shown diagrammatically a device package 210 comprising a base wall 211, side walls 212 and a cover sheet (not shown). Mounted on the base wall is a Peltier cooling element 213, which in turn carries a laser assembly (towards the left-hand side of Figure 6A) and a modulator 214.

The laser assembly comprises a laser-diode 216, first lens 217, an optical isolator 218 and a second lens 219, all of which are supported on a sub-mount 220 in turn carried by the Peltier cooling element 213. The sub-mount 220 has a V-shaped groove 221 in its upper surface, one wall 222 of which groove serves as a mounting surface for the laser-diode 216. The shape of the groove 221 is modified in the region between the laser-diode 216 and the modulator 214, in order to accommodate the lenses 217 and 219 and the optical isolator 218, on the optical axis of the laser assembly as a whole. As an alternative (not shown), the laser may be mounted on a first sub-mount, and the other optical components on a separate sub-mount.

Behind the laser-diode 216 there is provided a monitor photo-diode 223 which receives emission from the laser-diode 216, the output from the photo-diode 223 being used to control the drive current for the laser-diode 216, thereby to control the power thereof. The Peltier cooling element 213 is driven to control the temperature of the laser diode, and so the wavelength of its emission, the wavelength being monitored by a suitable tracking mechanism (not shown) mounted either externally or internally of the package 210. In this way, the wavelength of the emission from the laser-diode 216 may closely be controlled, by adjusting the temperature of that diode.

The modulator 214 is, as shown, of a Mach-Zehnder interferometer configuration, fabricated on a lithium niobate water. The modulator has an input waveguide 224 into which emissions from the laser-diode 216 are directed by lens 219, with that lens performing the required mode size adjustment for optimum coupling of the modulator to the laser-diode.

As shown, the plane of polarisation of light from the laser diode 216 is at 45° to the base wall 211 of the package 210, on account of the laser-diode 216

being mounted on surface 222 of the sub-mount 220. The optical isolator 218 rotates that plane of polarisation through 45°, so that the plane of polarisation is parallel to the base wall 211 of the package, corresponding to the launch polarisation state for the modulator 214 which, in this example is TE polarisation.

The output from the modulator 214 appears on waveguide 225, which is directly coupled to an output optical fibre pigtail 226, leading out of the package 210 for connection to another optical fibre or some other optical component, in a manner well known in the art. Connections to the various components within the package 210 are completed to external pins 227 of the package in a manner which is well understood and will not be described in further detail here.

Figures 7A and 7B show a second embodiment of this invention and like parts with those of Figures 6A and 6B are given like reference characters; those parts will not be described again here. The arrangement of Figures 7A and 7B differs from that of Figures 6A and 6B in that the laser-diode 216, lenses 217 and 219 and the optical isolator 218 are mounted on a conventional sub-mount having a planar upper surface parallel to the surface of the base wall 211 of the package 210. On the other hand, the base wall of the package carries a mount 230 over the region where the modulator 214 is supported, which mount 230 provides a mount surface 231 at 45° to the main area of the base wall, as shown in Figure 7B. The modulator 214 is carried by this surface, so that the plane of the wafer in which the modulator is fabricated lies at 45° to the plane of the base wall and thus is matched to the plane of polarisation of the light leaving lens 219. Alternatively, the base wall could be modified directly to provide mount surface 231 at the required angle, without employing a separate mount. In the arrangement of Figures 7A and 7B the Peltier cooler 213 does not extend beneath the modulator 214. In this way, the thermal capacity of the system supported by the cooler is reduced and better response times can thus be achieved, together with a reduction in the Peltier cooler drive current. In turn, this can give rise to more rapid and closer control over the wavelength of the light emitted by the laser-diode 216.

CLAIMS

1. An optical transmitter module comprising packaging means enclosing a laser assembly, an integrated optical circuit having an input waveguide and an output waveguide, an optical fibre stub having one end supported to receive light from the laser assembly and the other end of the optical fibre stub being optically coupled to the input waveguide of the optical circuit, and an output optical fibre in optical communication with the output waveguide of the optical circuit and leading out of the packaging means, whereby light emanating from the laser assembly is subjected to data-encoding by the optical circuit before leaving the packaging means.

2. An optical transmitter module as claimed in claim 1, wherein the laser assembly is in the form of an hermetically-sealed or non-hermetically-sealed sub-module mounted within said packaging means, the optical fibre stub entering in a sealing manner the laser sub-module to receive light from the laser assembly.

3. An optical transmitter module as claimed in claim 2, wherein the laser sub-module includes a Peltier cooler on which the laser assembly components are mounted, whereby the emission wavelength of the laser assembly may be controlled by suitable driving of the cooler.

4. An optical transmitter module as claimed in claim 2 or claim 3, wherein a mount is provided within the laser sub-module and to which the end portion of the fibre stub is attached.

5. An optical transmitter module as claimed in claim 4, wherein the end of the fibre stub within the laser sub-module is formed as a lens to collect light emitted by the laser assembly.

6. An optical transmitter module as claimed in claim 1, wherein a mounting element is provided within the packaging means and carries the laser assembly, and support means is provided on the mounting element for supporting the said one end of the optical fibre adjacent the laser assembly.

7. An optical transmitter module as claimed in claim 6, wherein the mounting element comprises a Peltier cooler, whereby the emission wavelength of the

laser assembly may be controlled by suitable driving of the cooler.

8. An optical transmitter module as claimed in claim 1, wherein the packaging means has a base wall and one of the laser assembly and the integrated optical circuit is carried on a mounting surface which lies at an acute angle to the base wall whereby the polarisation plane of light leaving the laser assembly matches the launch polarisation plane of the integrated optical circuits.

9. An optical transmitter module as claimed in claim 8, wherein the laser assembly includes an optical isolator which rotates the plane of polarisation of the light through $+\alpha°$ and said mounting surface lies at $-\alpha°$ to the base wall.

10. An optical transmitter module as claimed in claim 8 or claim 9, wherein the mounting surface is provided on a sub-mount supported on the base wall of the package.

11. An optical transmitter module as claimed in any of claims 8 to 10, wherein the laser assembly includes a semi-conductor laser and the laser is carried on the mounting surface.

12. An optical transmitter module as claimed in claim 11, wherein the laser assembly includes a single stage optical isolator, which isolator also is mounted on said mounting surface.

13. An optical transmitter module as claimed in any one of claims 8 to 10, wherein the integrated optical circuit is mounted on said mounting surface.

14. An optical transmitter module as claimed in any of claims 8 to 10, wherein the mounting surface is provided on a Peltier cooler.

15. An optical transmitter module as claimed in any of the preceding claims, wherein the laser assembly includes a semi-conductor laser and feedback means arranged to sense the wavelength of the emission from the laser and to feedback to the laser a signal which controls the frequency of the emission.

16. An optical transmitter module as claimed in claim 15, wherein, the feedback means operates on an optical basis and feeds back an optical signal to the semi-conductor laser.

17. An optical transmitter module as claimed in any of the preceding claims, wherein the laser assembly includes a semi-conductor laser and a monitor

photodiode arranged to receive light from the laser, the output of the photodiode being used to control the output power of the laser.

18. An optical transmitter module as claimed in any of the preceding claims, wherein said fibre stub is a polarisation-maintaining optical fibre.

19. An optical transmitter module as claimed in any of claims 1 to 17, wherein said fibre stub is a singlemode optical fibre.

20. An optical transmitter module as claimed in any of the preceding claims, wherein said fibre stub is directly connected to the input waveguide of the integrated optical component.

21. An optical transmitter module as claimed in any of the preceding claims, wherein the integrated optical circuit comprises a modulator.

22. An optical transmitter module as claimed in claim 21, wherein the modulator comprises one of a phase modulator and a Mach-Zehnder interferometer.

23. An optical transmitter module as claimed in any of the preceding claims, wherein the optical circuit includes one or more of an attenuator, an optical splitter, an optical combiner, an optical switch and an optical filter.

24. An optical transmitter module as claimed in any of the preceding claims, wherein said one end of the fibre stub is formed as a lens to collect light emitted by the laser assembly.

25. An optical transmitter module as claimed in any of the preceding claims, wherein the laser assembly includes a semi-conductor laser and an optical isolator arranged between the laser and said one end of the fibre stub.

26. An optical transmitter module as claimed in any of the preceding claims, wherein the packaging means comprises a base wall on which the laser assembly and the integrated optical circuit are separately mounted, side walls upstanding from the base wall, and a cover sheet sealed to the side walls so as wholly to enclose the laser assembly and the integrated optical circuit.

27. An optical transmitter module as claimed in any of the preceding claims, wherein the packaging means is hermetically-sealed to isolate the laser assembly and the integrated optical circuit from the external environment.

28. An optical transmitter module comprising packaging means having a base

wall and enclosing a laser assembly including an optical train having an output lens, an integrated optical circuit optically coupled by said lens to the laser assembly to receive light therefrom and arranged to perform data-encoding on said light, one of the laser assembly and the integrated optical circuit being carried on a mounting surface which lies at an acute angle to the plane of the base wall whereby the polarisation plane of light leaving the laser assembly matches the launch polarisation plane of the integrated optical circuit.

29. An optical transmitter module as claimed in claim 28, wherein the laser assembly includes an optical isolator which rotates the plane of polarisation of the light through $+\alpha°$ and said mounting surface lies at $-\alpha°$ to the base wall.

30. An optical transmitter module as claimed in claim 28 or claim 29, wherein the mounting surface is provided on a sub-mount supported on the base wall of the package.

31. An optical transmitter module as claimed in any of claims 28 to 30, wherein the laser assembly includes a laser diode and the laser diode is carried on the mounting surface.

32. An optical transmitter module as claimed in claim 31, wherein the laser assembly includes a single stage optical isolator, which isolator also is mounted on said mounting surface.

33. An optical transmitter module as claimed in any one of claims 28 to 30, wherein the integrated optical circuit is mounted on said mounting surface.

34. An optical transmitter module as claimed in any of the preceding claims, wherein an output optical fibre is in optical communication with the output of the optical circuit which fibre leads out of the packaging means.

Figure 1
(Prior Art)

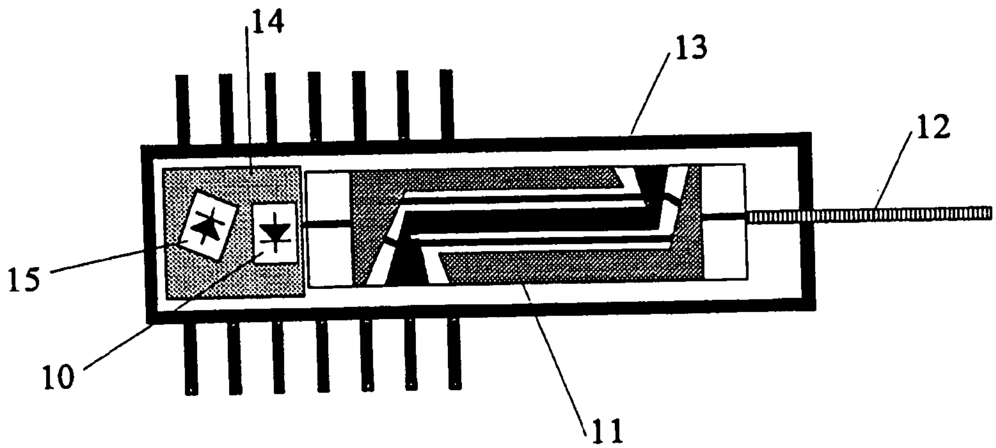


Figure 2
(Prior Art)

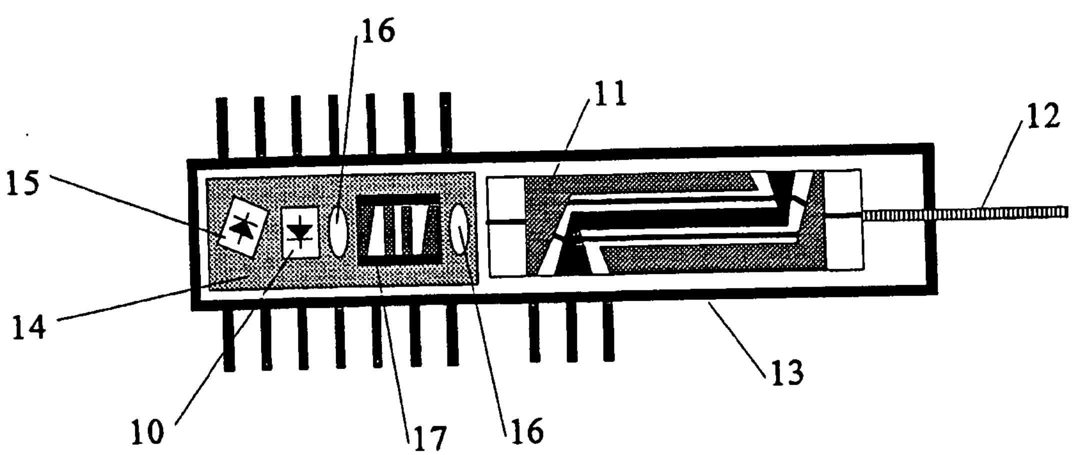


Figure 3

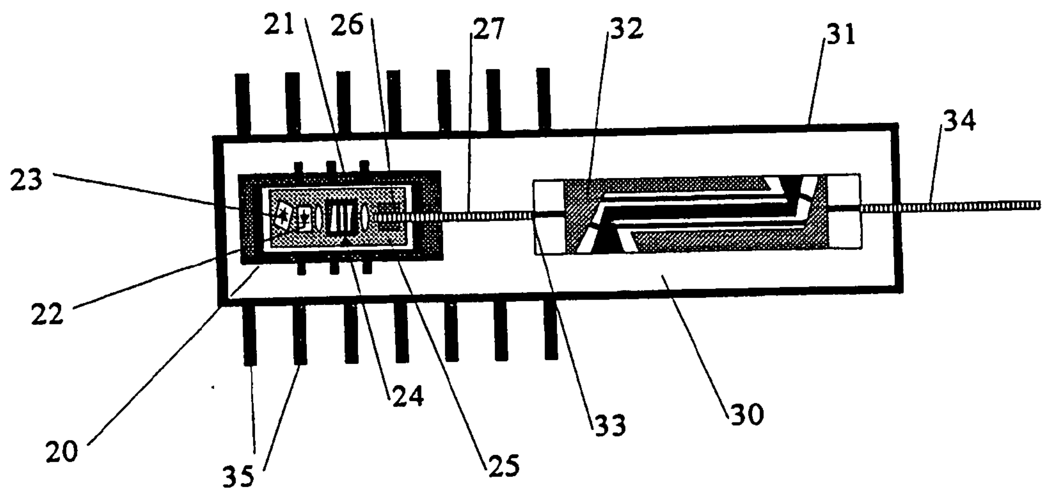


Figure 4

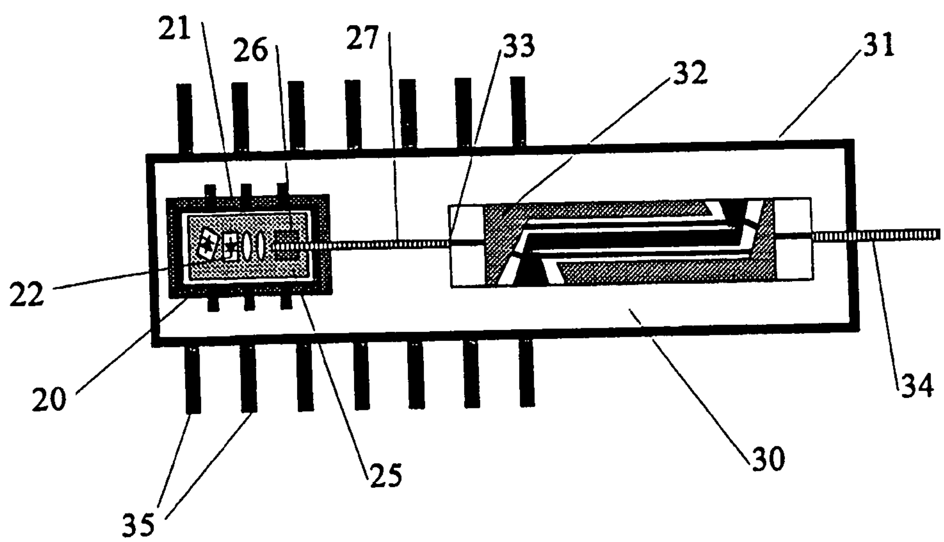


Figure 5A

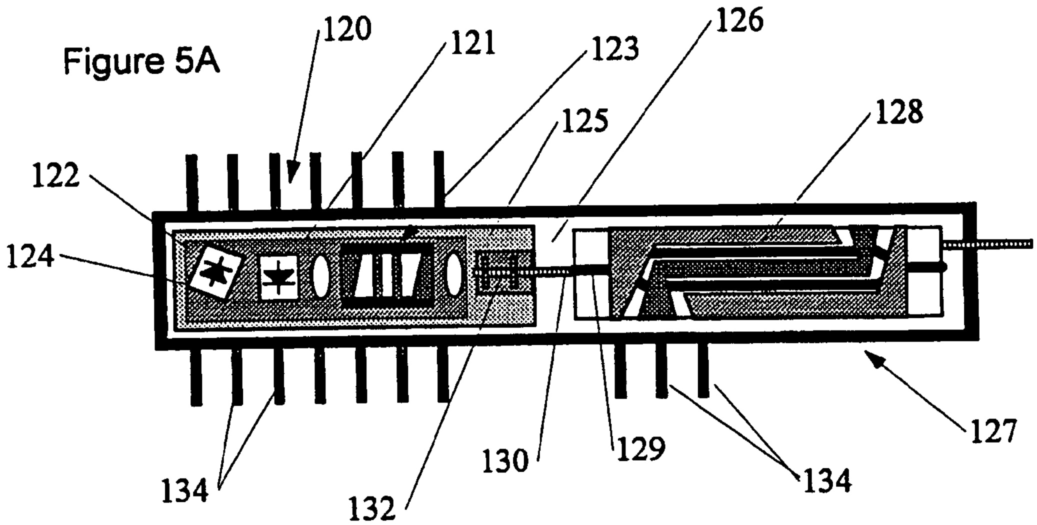


Figure 5B

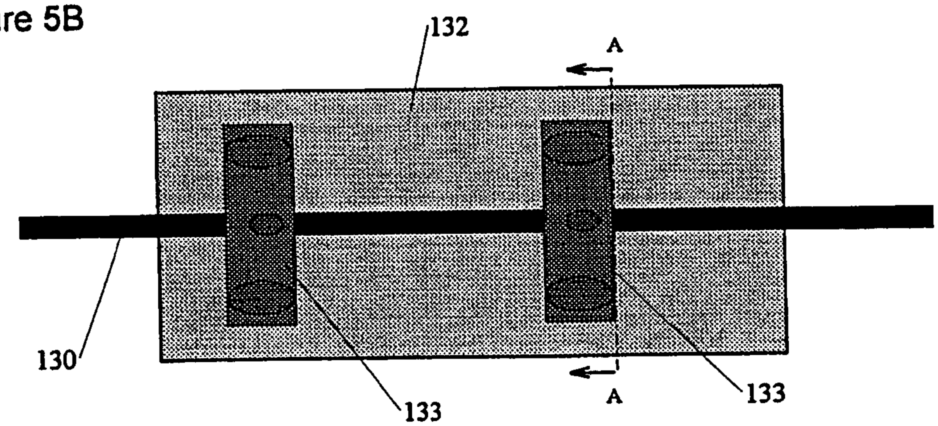


Figure 5C

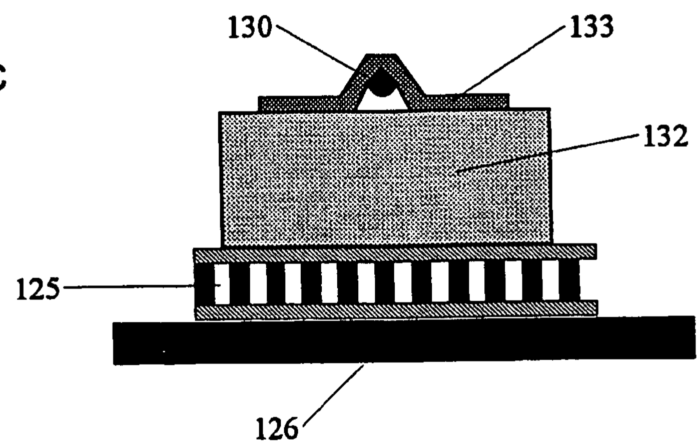


Figure 6A

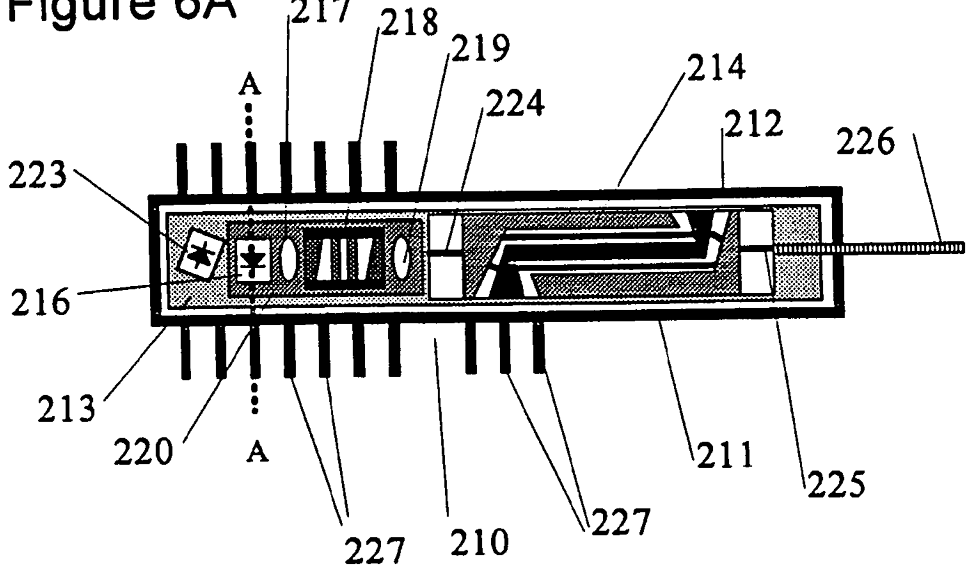


Figure 6B

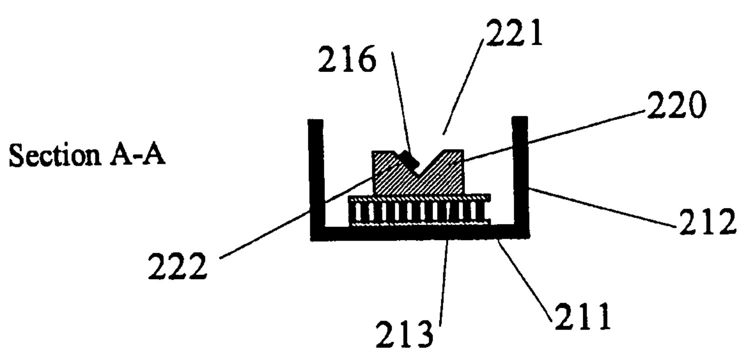


Figure 7A

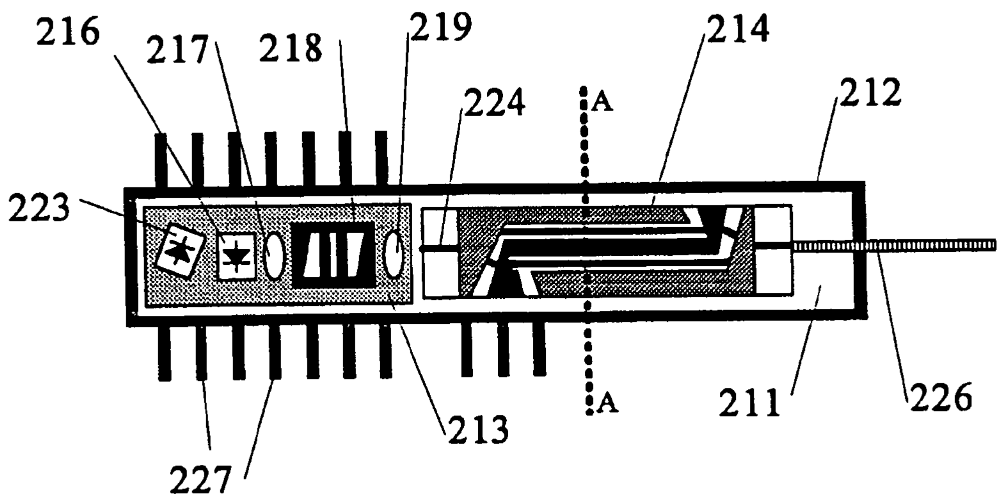
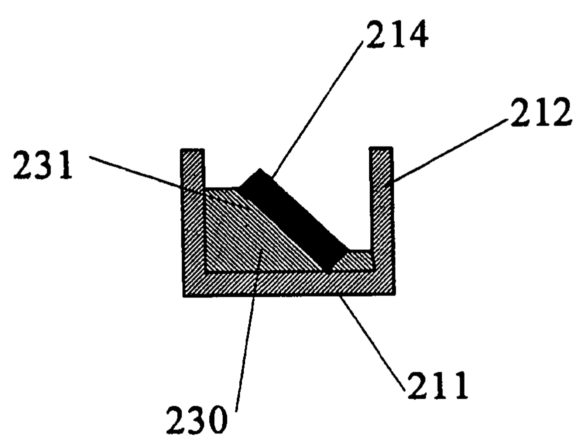


Figure 7B



INTERNATIONAL SEARCH REPORT

Intc 'ional Application No
PCT/GB 99/00537

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G02B6/42 H01S3/025

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G02B H01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 097, no. 007, 31 July 1997 & JP 09 069819 A (NEC CORP), 11 March 1997	1,21
A	see abstract	2,6,8, 15,17, 18,20, 22,23, 26-28

A	PATENT ABSTRACTS OF JAPAN vol. 016, no. 332 (E-1236), 20 July 1992 & JP 04 099081 A (FUJITSU LTD), 31 March 1992 see abstract	1,21,22, 28

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 June 1999	14/06/1999

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 098, no. 001, 30 January 1998 & JP 09 252164 A (MITSUBISHI ELECTRIC CORP), 22 September 1997 see abstract	1,21,28
A	US 5 712 940 A (TIEMEIJER LUKAS F ET AL) 27 January 1998 see column 2, line 35-36 see column 4, line 10-26 see column 5, line 28; figures 1,2	1,8,28
A	PATENT ABSTRACTS OF JAPAN vol. 017, no. 066 (P-1484), 9 February 1993 & JP 04 274204 A (FUJITSU LTD), 30 September 1992 see abstract	1,28
A	PATENT ABSTRACTS OF JAPAN vol. 014, no. 104 (P-1013), 26 February 1990 & JP 01 307725 A (NEC CORP), 12 December 1989 see abstract	28

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Information on patent family members

Inte 'onal Application No
PCT/GB 99/00537

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		WO 9624872 A	15-08-1996
		JP 9511848 T	25-11-1997

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